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ROCKETBORNE FAR-INFRARED CIRCULAR-VARIABLE FILTER SPECTROMETER DEVELOPMENT

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13. ABSTRACT

During the period covered by this contract, May 25, 1970, to June 30, 1974, the research effort initiated earlier under Contract F19628-67-C-0322 was continued. This effort led to the development of high-vacuum liquid-helium cooled circular-variable filter spectrometers. These spectrometers have been successfully used in rocketborne applications to make *in situ* measurements of the overhead spectral radiance, as a function of rocket height, of the atmospheric emission species in the long wavelength region of the infrared. This research led to the advancement of the state-of-the-art in such aerospace infrared measurements and in several related areas such as the detector-preamplifier interface and cold bearing design. A total of five rocket flights were conducted which resulted in measurements of the overhead radiance, as a function of rocket altitude between 45 and 200 km, of the atmospheric emissions in the 7 to 24 μm range of the infrared. Dominant species at 9.6 and 15 μm are attributed to ozone and carbon dioxide.

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Dean F. Kimball

RELATED CONTRACTS AND PUBLICATIONS

F19628-67-C-0322
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Clair L. Wyatt, Alvin M. Despain, and Doran J. Baker, "An Optimum System Synthesis for Optical Radiometric Measurements", *Scientific Report No. 1*, AFCRL-68-0329, Contract No. F19628-67-C-0322, Electro-Dynamics Laboratories, Utah State University, Logan, Utah, June 1, 1968.

A.T. Stair, Jr., *Results of the Recent Auroral Probe Flight*, paper presented at the Fifth Midcourse Measurements Meeting, conducted by the Willow Run Laboratories of the University of Michigan, at the Institute for Defense Analysis, Arlington, Virginia, November 4, 1969.

Clair L. Wyatt, Doran J. Baker, and D. Gary Frodsham, *A Frequency Compensating Electrometer Preamplifier for use with Helium-Cooled Infrared Detectors*, paper presented at the Sixth Midcourse Measurements Meeting, conducted by the Willow Run Laboratories of the University of Michigan, at El Segundo, California, February 11, 1970.

A.T. Stair, Jr., and Dean F. Kimball, *High Altitude Radiance Measurements with the Rocket Borne CVF Spectrometer*, paper presented at the Sixth Midcourse Measurements Meeting, conducted by the Willow Run Laboratories of the University of Michigan, at the Aerospace Corporation, El Segundo, California, February 11, 1970.

Clair L. Wyatt, "Design Evaluation Report for Model HS-1 Helium-Cooled Circular-Variable Filter Spectrometer", *Research and Design Evaluation Report*, submitted to Contract Monitor Dean F. Kimball under Contract No. F19628-72-C-0289, Electro-Dynamics Laboratories, Utah State University, Logan, Utah, December 31, 1970.

D. Gary Frodsham and Clair L. Wyatt, *A Low Noise Preamplifier for Helium-Cooled Infrared Detectors*, paper presented at the Eleventh Midcourse Measurements Meeting, conducted by the Willow Run Laboratories of the University of Michigan, at San Bernardino California, April 20, 1971.

A.T. Stair, Jr., *Preliminary Report -- Auroral Flight*, paper presented at the Eleventh Midcourse Measurements Meeting, conducted by the Willow Run Laboratories of the University of Michigan, at the Aerospace Corporation, San Bernardino, California, April 1971.

Clair L. Wyatt, "A Three Channel Scanning Radiometer -- Model WS-1", *Scientific Report No. 2*, AFCRL-70-0384, Contract No. F19628-67-C-0322, Electro-Dynamics Laboratories, Utan State University, Logan, Utah, June 1, 1971.

Clair L. Wyatt, "Infrared Helium-Cooled Circular-Variable Spectrometer, Model HS-1", *Final Report*, AFCRL-71-0340, Contract No. F19628-67-C-0322, Electro-Dynamics Laboratories, Utah State University, Logan, Utah, September 15, 1971.

Ruey Y. Han, Lawrence R. Megill, and Clair L. Wyatt, "Reduction and Analysis of Natal Flight Data", *Final Report*, AFCRL-72-0018, Contract No. F19628-70-C-0215, Electro-Dynamics Laboratories, Utah State University, Logan, Utah, January 11, 1972.

Clair L. Wyatt, et al., *High Altitude Spectral Measurement in the LWIR (U)*, paper presented at the Eighteenth Midcourse Measurements Meeting, ARPA-T10-73-2, SECRET, at the Defense Advanced Research Projects Agency, 1400 Wilson Boulevard, Arlington, Virginia, March 1973.

Ruey Y. Han, L.R. Megill, and Clair L. Wyatt, "Rocket Observation of the Equatorial $O_2(^1\Delta_g)$ Emission After Sunset", *Journal of Geophysical Research*, 78(27), pp. 6140-6149, 1973.

Clair L. Wyatt and Ralph H. Haycock, "High Thermal Conductivity Bearing for Rotating Devices at Liquid-Helium Temperatures", *Review of Scientific Instruments*, 45(3), pp. 434-437, 1974.

Clair L. Wyatt and David E. Morse, "Design Evaluation Report for Laboratory Spectrometer Preamplifier, Model LSP-1", *Research and Design Evaluation Report*, Submitted to Contract Monitor Dean F. Kimball under Contract No. F19628-72-C-0264, Electro-Dynamics Laboratories, Utah State University, Logan, Utah, 30 April 1974.

Clair L. Wyatt and Roy W. Esplin, "Multiplexed Dispersive Spectrometers using Reduced Background IR Detectors", *Applied Optics*, 13( ), 1974.

Clair L. Wyatt, Doran J. Baker, and D. Gary Frodsham, "A Direct Coupled Low Noise Preamplifier for Cryogenically-Cooled Photoconductive IR Detectors", *Infrared Physics*, accepted for publication in 1974.

Clair L. Wyatt, "Liquid-Helium Cooled Rocketborne Spectrometer, *Applied Optics*, Submitted for publication in 1974.

A.T. Stair, Jr., James C. Ulwick, Doran J. Baker, Clair L. Wyatt, and Kay D. Baker, "Altitude Profiles of Infrared Radiance of O_3 (9.6 µm) and CO_2 (15 µm)", *Geophysical Research Letters*, 1(3), 1974.

PREFACE

The work research efforts described in this report represent the culmination of efforts of the entire staff of the Aerospace Instrumentation Laboratory of the Electro-Dynamics Laboratories, Utah State University, Logan, Utah. The contributions of A.T. Stair, Dean F. Kimball, and Ned Wheeler of the Air Force Cambridge Research Laboratories are acknowledged.

TABLE OF CONTENTS

INTRODUCTION

The primary objective of the research performed under contract F19628-70-C-0289 was to design, fabricate, test and calibrate two circular-variable filter spectrometers of high sensitivity to be flown on vertical sounding rockets, such as the Black Brant VC, for the purpose of making measurements of the spectral radiance of aurora and airglow. These instruments were to be flown, recovered, and refurbished as appropriate to provide three flights.

Another objective related to this contract was the design, fabrication, test and calibration of a three-channel scanning radiometer for the measurement of atmospheric emissions in the night time equatorial sky. The instrument was fabricated under Contract No. F19628-67-C-0322 and the data was analyzed and reduced under Contract No. F19628-70-C-0215.

Another objective related to this contract was the design of a laboratory spectrometer preamplifier to be utilized in a high-vacuum cryogenic laboratory system.

This contract work, and this report, are concerned with the development of the instrumentation hardware and evaluation of performance rather than with the evaluation of the atmospheric airglow data obtained in most cases.

THE INFRARED HELIUM-COOLED CIRCULAR-VARIABLE SPECTROMETER

In total, five rocket flights were conducted under two contracts, two under Contract No. F19628-67-C-0322, and three under Contract No. F19628-70-C-0289. Complete listings of these flights with details of the rocket flight, instrument specifications, atmospheric conditions, results, and system performance are given in Tables I through V. These instruments were all designed to obtain measurements of atmospheric radiations in the infrared portion of the optical spectrum using cryogenic low-temperature techniques.

Introduction

The last two rocket flights, were flown as part of the 1973 and 1974 "ICECAP" Auroral Measurements Program on this contract. The instruments used on these flights are described in the following paper.

Clair L. Wyatt, "Liquid-Helium cooled Rocketborne Spectrometer, *Applied Optics*, submitted for publication in 1974.

Abstract

The infrared spectrometer that successfully recorded atmospheric spectra between 45 and 200 km in the 1973 and 1974 "ICECAP" Auroral Measurements Program is described. The instrument continuously scanned the 6.75-23.2 μm spectral region at the rate of 2 scans per second. The instrument resolution of the spectrometer, which employed a circular-variable interference filter (CVF), ranged from 3 to 4 percent. The entire optical subsection, silicon-arsenic detector, CVF irtran VI lens, baffle, and removable cold cover were cooled below 10°K in a high-vacuum Dewar system. The noise equivalent spectral radiance (NESR) of the spectrometer, at 22 μm, was 1×10^{-11} watt $cm^{-2}sr^{-1}\mu m^{-1}$. The electronic system was dc reset with an opaque mask mounted over the filter segment joints to provide a zero signal reference. The dominant emission features observed on both flights were 9.6 μm O_3 and 15 μm CO_2.

TABLE I

Summary of First Flight

Rocket: Aerobee 150 No. AA1

Flight Date/Time: 23 October 1969 / 00:05 hr. L.T.

Location: Ft. Churchill, Manitoba, Canada

Instrument: WW-12

Detector Type: GE-Hg

Free Spectral Range: 4.0 to 12.7 μm

Resolution: 3-4 percent

NESR: 3.5×10^{-8} (watt $cm^{-2}sr^{-1}\mu m^{-1}$) @ 11 μm.

Scanning Rate: 2 scans per second

Conditions: Class 1 Aurora

Results: Some spectra were obtained between 68 and 124 km at 9.6 μm.

System Performance: A rapid rise in temperature occurred beginning at launch resulting in system failure due to the detector temperature rising out of specifications.

The 77°K blackbody background experienced on both high and low gain channels resulted from 2π steradian baffle radiation (out of the field of view) scattering off the lens into the field of view.

Every aspect of the instrument design, support hardware, tower facilities and monitoring provisions were inconvenient and reflect lack of experience in handling cryogenic systems at the launch facility.

Conclusion: Some useful data were obtained as later flights verified. A major value of the program was in obtaining field experience that enabled the later flights to become successful.

TABLE II

Summary of Second Flight

Rocket: Black Brant, A16.006-3

Flight Date/Time: 23 March 1971 / 23:26 hr. L.T.

Location: Ft. Churchill, Manitoba, Canada

Instrument: HS-1

Detector Type: Ge-Hg

Free Spectral Range: 4-13 μm

Resolution: 3-4 percent

NESR: 5×10^{-11} (watt $cm^{-2}sr^{-1}\mu m^{-1}$) @ 11 μm.

Scanning Rate: 2 scans per second

Conditions: Class 1 Aurora

Results: No useful atmospheric spectra were obtained.

System Performance: The cryogenic system performed perfectly. Temperature probes indicated normal temperatures until reentry. Hold time proved to be about four hours.

A hot object, probably part of the nosecone or removable instrument cover, remained in the field of view producing large scintillations in the output.

A motor shaft coupler failed just after apogee resulting in failure of the filter drive and dc reset electronics.

A long time constant of recovery from high level signals was observed on the Ge-Hg detector, as well as numerous spike-like pulses that were attributed to natural gamma ray background excitation of the detector.

Conclusion: A more positive method of disposing of the clam shell nosecone and removable instrument cover was needed. The filter drive system; consisting of mounts, bearings, and couplers, was subsequently examined and modified to eliminate failure problems in that subsystem. In addition, a study of the long time constants and gamma response of Ge-Hg was undertaken and the decision made to use Si-As in the future flights.

TABLE III

Summary of Third Flight

Rocket: Black Brant, A18.006-5

Flight Date/Time: 5 December 1972 / 01:45 hr. L.T.

Location: Ft. Churchill, Manitoba, Canada

Instrument: HS-1B-1

Detector Type: Si-As

Free Spectral Range: 6.5-24 μm

Resolution: 3-4 percent

NESR: 1×10^{-11} (watt $cm^{-2}sr^{-1}\mu m^{-1}$) @ 22 μm.

Scanning Rate: 2 scans per second

Conditions: Class 1 Aurora

Results: Some spectra were obtained between 95 and 120 km at 15.0 μm.

System Performance: The otherwise successful flight was compromised by an electrical short circuit between the instrument and the payload that introduced excessive noise and reduced the system responsivity by shorting out the detector bias.

The internal calibration functioned properly making it possible to put absolute numbers on the airglow data obtained during the ascent and decent of the payload.

Conclusion: The harnessing of the payload was examined and it was learned that a cable caught on the instrument cover clamp as the nose tip opened cutting through the insulation, resulting in a loss of detector bias. The harnessing of the nose tip opening mechanism was redesigned to eliminate this problem.

TABLE IV

Summary of Fourth Flight

Rocket: Black Brant, A18.006-2

Flight Date/Time: 22 March 1973 / 02:12 hr. L.T.

Location: Poker Flat, Alaska

Instrument: HS-1B-1B

Detector Type: Si-As

Free Spectral Range: 7-23 μm

Resolution: 3-4 percent

NESR: 1×10^{-11} (watt $cm^{-2}sr^{-1}\mu m^{-1}$) @ 22 μm.

Scanning Rate: 2 scans per second

Conditions: Class IBC2 post auroral breakup.

Results: Completely successful with spectra being obtained continuously between 42 and 185 km. Major emission features were observed at 15.0 and 9.6 μm.

Conclusion: The total system consisting of payload and instrument have proven, in this flight, to be a working system for the obtaining of the vertical profile of overhead atmospheric spectral radiance in the infrared. The long time constant of recovery from large signals was not apparent with the Si-As detector. Throughout the entire duration of the flight only several gamma pulses were recorded.

TABLE V

Summary of Fifth Flight

Rocket: Black Brant, A18.006-4

Flight Date/Time: 14 February 1974 / 21:07 hr. D.S.T.

Location: Poker Flat, Alaska

Instrument: HS-1B-2B

Detector Types: Si-As

Free Spectral Range: 7-23 μm

Resolution: 3-4 percent

NESR: 1×10^{-11} (watt $cm^{-2} sr^{-1} \mu m^{-1}$) @ 22 μm.

Scanning Rate: 2 scans per second

Conditions: Quiet Sky

Results: Completely successful with spectra being obtained continuously between 67 and 200 km. Major emission features were observed at 15 and at 9.6 μm.

Conclusion: This flight confirms that the payload and instrument have proven again to be a working system for the obtaining of the vertical profile of overhead atmospheric radiance in the long wavelength infrared.

Fundamentals of Radiometric Detection

It was necessary to perform some very basic studies in order to achieve the stated contract objectives. Some of these studies resulted in an advancement in the state-of-the-art, while other studies resulted in the advancement of specific technical skills by USU personnel.

One of the initial studies is related to the area of fundamentals of radiometric dectection. This study, its results and implications, are discussed in the following scientific report.

Clair L. Wyatt, Alvin M. Despain, and Doran J. Baker, "An Optimum System Synthesis for Optical Radiometric Measurements", *Scientific Report No. 1*, AFCRL-68-0329, Contract No. F19628-67-C-0322, Electro-Dynamics Laboratories, Utah State University, Logan, Utah; June 1, 1968.

Abstract

The minimum detectable signal of an optical radiometer was optimized as a function of modulation and correlation waveforms, and relative amplitudes of source, reference, and noise levels. The mathematical model considers the radiometer as a device to estimate the variance of a Gaussian random process with zero mean. It was found that the optimum system is one which "looks" at the source for one half of the period and then abruptly switches to the reference for the remainder of the period. The optimum correlation detection waveform is realized by an ideal switch which reverses polarity every half cycle. The optimum modulated radiometer includes the dc (non-modulated) radiometer as a special case for which $1/f$ noise and drift can be neglected.

Because of the relative amplitudes of the detector noise and the unknown and source photon noise, no loss in optimality is inferred by using a non-zero reference source such as is required in a nulling system.

The theoretical results for three commonly encountered waveforms were computed and laboratory measurements confirm the results that were interpreted in terms of the detector parameter NEP. These are: (1) The optimum radiometer as described above for which the minimum detectable signal is P_m = 2 NEP. (2) The sine wave radiometer, which utilizes a tuned ac amplifier to select the fundamental sine wave component of the modulated signal for which P_m = 2.46 NEP. (3) The radiometer which produces a triangular wave resulting from the convolution of a chopper blade with an aperature of the same width for

which P_m = 4 NEP. The experiment demonstrated the feasibility of the optimum system.

Detector-Preamplifier Interface

Another area of study, that was directly related to the success of this program, is the interface between the extrinsic infrared detectors and the electronics. Utah State University engineers achieved a major breakthrough in the area of cryogenic preamplifiers by demonstrating the superior characteristics of the negative-feedback electrometer preamplifier. This amplifier, now known as the trans-impedance amplifier (TIA), is used almost universally by the infrared community. The following three papers are related to this development.

Clair L. Wyatt, Doran J. Baker, and D. Gary Frodsham, *A Frequency Compensating Electrometer Preamplifier for use with Helium-Cooled Infrared Detectors*, paper presented at the Sixth Midcourse Measurements Meeting, conducted by the Willow Run Laboratories of the University of Michigan, at El Segundo, California, February 11, 1970.

Abstract

A low noise, operational feedback preamplifier circuit was developed that provides frequency response compensation for the input and detector capacitance of high impedance germanium detectors. This preamplifier was developed for the first rocket-borne helium-cooled spectrometer which was flown at Ft. Churchill, Manitoba, Canada, in October of 1969. The instrument is a low resolution auroral spectrometer probe.

The time constant of the detector preamplifier system is given by $T_c = R_f(C_f + C_T)/A$ where R_f and C_f are the feedback parameters, C_T is the total input and detector capacitance, and A is the open loop gain of the amplifier. The compensation networks also emphasize the high-frequency preamplifier input noise; however, improvements of about 2 orders of magnitude are possible without detector D* performance degradation.

D. Gary Frodsham and Clair L. Wyatt, *A Low Noise Preamplifier for Helium-Cooled Infrared Detectors*, paper presented at the Eleventh Midcourse Measurements Meeting, Conducted by the Willow Run Laboratories of the University of Michigan, at San Bernardino, California, April 20, 1971.

Abstract

Frequency compensating techniques applied to helium-cooled infrared detectors operating at essentially zero background are ultimately limited by preamplifier noise. The compensating amplifier can null out the frequency roll-off effects of input capacitance, but amplification of high frequency amplifier noise and capacitive microphonisms are limits to its usefulness. A detector-preamplifier package has been developed to adapt low noise silicon JFETS to the helium temperature environment. The package controls the JFET temperature at approximately 77°K by self heating, while shielding the detector from hot FET thermal emissions. Microphonic noise is minimized by keeping the leads short and by holding them securely. This study demonstrates that the limiting noise of this silicon JFET preamplifier is lower by several orders of magnitude than for preamplifiers using MOSFETS, germanium JFETS, or vacuum tubes.

Clair L. Wyatt, Doran J. Baker, and D. Gary Frodsham, "A Direct Coupled Low Noise Preamplifier for Cryogenically-Cooled Photoconductive IR Detectors", *Infrared Physics*, accepted for publication in 1974.

Abstract

The trans-impedance preamplifier (TIA) is a direct-coupled negative feedback operational scheme that has been successfully applied to ultra-high impedance cryogenically-cooled photoconductive detectors. All time constants associated with this circuit are reduced by the open-loop gain of the preamplifier. Such an amplifier with a transfer impedance resistor of 9×10^{10} Ω yields a frequency response that is flat (i.e., uniform) to 700 Hz. This is a factor of 3800-times the uncompensated detector preamplifier response of 0.184 Hz.

The TIA amplifier has significant advantages over the more commonly used circuits. These result from the *virtual ground* which provides improved linearity since the detector bias voltage is maintained constant, reduced microphonic sensitivity and reduced cross talk in multiple element detector arrays since the preamplifier input impedance and input signal voltage are both reduced by the open loop gain of the preamplifier.

The preamplifier noise in the TIA scheme degrades the detector detectivity in the same way as for other *equilization* schemes and must therefore be minimized. Relations are developed that yield thermal noise and preamplifier noise limitations

for the TIA preamplifier.

This preamplifier design was successfully used in an LWIR spectrometer which was launched on a Black Brant VC rocket at Poker Flat, Alaska, on March 22, 1973. The spectrometer obtained auroral emission spectra from 6.72 to 23.2 μm over an altitude range of 45-185 km. Dominant features at 9.6 and 15 μm were attributed to ozone and carbon dioxide.

Cold Bearings

Another area of study, that was directly related to the success of this program, deals with the problems of the cooling of the optical components within a high-vacuum cryogenic environment. A major goal of the HS-1 system design was to avoid the necessity to use gaseous-helium to provide thermal contact with the optical components, particulary the motor driven circular-variable filter. The following paper details the results of that successful effort.

Clair L. Wyatt and Ralph H. Haycock, "High Thermal Conductivity Bearing for Rotating Devices at Liquid-Helium Temperatures", *Review of Scientific Instruments*, 45(3), pp. 434-437, 1974.

Abstract

A ball bearing of high thermal conductivity has been developed to provide conductive cooling for rotating optical devices at 2 rps. The bearings are made of pure copper which is silver coated. The bearing and hub are spring loaded to provide constant contact pressure even under changing temperature conditions. The bearing can cool a 310 g circular variable optical filter to 10K within 83 min. The bearing was utilized in a helium-cooled spectrometer which was launched on a Black Brant VC rocket at Poker Flat, Alaska, on 22 March 1973, during a condition of post auroral breakup. Spectra were obtained from 185 km to about 40 km. Some 630 spectral scans covering the range of 6.75 to 23.3 μ were telemetered. The special bearing performed well through all portions of the rocket trajectory.

Miscellaneous Problems

There are many other aspects to the development of helium-cooled circular variable spectrometer systems in the general areas of cryogenic, environmental, radiometric, optical, and electronic system design that are discussed in the following report.

Clair L. Wyatt, "Design Evaluation Report for Model HS-1 Helium-Cooled Circular-Variable Filter Spectrometer", *Research and Design Evaluation Report*, submitted to Contract Monitor Dean F. Kimball under Contract No. F19628-72-C-0289, Electro-Dynamics Laboratories, Utah State University, Logan, Utah; December 31, 1970.

No Abstract

The evolution from the WW-12 system (the first flight instrument) to the HS-1 system (the final design configuration) is reported in detail in the Final Report on Contract No. F19628-67-C-0322.

Clair L. Wyatt, "Infrared Helium-Cooled Circular-Variable Spectrometer (Model HS-1)", *Final Report*, AFCRL-71-0340, Contract No. F19628-67-C-0322, Electro-Dynamics Laboratories, Utah State University, Logan, Utah, September 15, 1971.

Abstract

The design, evaluation, calibration and post-flight evaluation of a helium-cooled circular-variable filter (CVF) spectrometer are given. The system uses a 4-15 μ CVF and a mercury-doped germanium detector operated under helium temperature background conditions. Negative-feedback frequency com pensating preamplifiers and dc reset signal-conditioning amplifiers are used to achieve an optimum frequency response and sensitivity combination for auroral and airglow measurements. A special thermally-conductive bearing has been developed to enable the rotating CVF to be cryogenically cooled. The Instrument was successfully launched on 23 March 1971. System performance data analyses are given and related to anomalous features which were observed in the data.

Preliminary Data Report

Preliminary data reports were made on the first rocket flight of October 1969, the second rocket flight of March 1971, and the fourth rocket flight of March, 1973, as follows:

A.T. Stair, Jr., *Results of the Recent Auroral Probe Flight*, paper presented at the Fifth Midcourse Measurements Meeting, conducted by the Willow Run Laboratories of the University of Michigan, at the Institute for Defense Analysis, Arlington, Virginia, November 4, 1969.

No Abstract

A.T. Stair, Jr., and Dean F. Kimball, *High Altitude Radiance Measurements with the Rocket Borne CVF Spectrometer*, paper presented at the Sixth Midcourse Measurements Meeting, conducted by the Willow Run Laboratories of the University of Michigan, at the Aerospace Corporation, El Segundo, California, February 11, 1970.

No Abstract

A.T. Stair, Jr., *Preliminary Report -- Auroral Flight*, paper presented at the Eleventh Midcourse Measurements Meeting conducted by the Willow Run Laboratories of the University of Michigan, at the Aerospace Corporation, San Bernardino, California, April 1971.

No Abstract

Clair L. Wyatt, et al., *Altitude Spectral Measurement in the LWIR (U)*, paper presented at the Eighteenth Midcourse Measurements Meeting, ARPA-TIO-73-2, SECRET, at the Defense Advanced Research Projects Agency, 1400 Wilson Boulevard, Arlington, Virginia, March 1973.

No Abstract

The rocket flights of the two infrared helium-cooled circular-variable spectrometers, during the 1973 and 1974 "ICECAP" Auroral Measurements Program, obtained spectra between approximately 42 and 200 km over the spectral range of 7-23 μm. The following paper is a preliminary report on the data obtained on these two flights.

A.T. Stair, Jr., James C. Ulwick, Doran J. Baker, Clair L. Wyatt, and Kay D. Baker, "Altitude Profiles of Infrared Radiance of O_3 (9.6 μm) and CO_2 (15 μm)", *Geophysical Research Letters*, 1(3), 1974.

Abstract

The infrared spectrum of the upper atmospheric emissions between 7 and 23 μm has been measured with two spectrometers carried to high altitude by sounding rockets. Radiance profiles of O_3 (9.6 μm) and CO_2 (15 μm) radiations have been obtained to nearly 100 and 150 km, respectively.

THE THREE-CHANNEL SCANNING RADIOMETER

Another objective related to this contract was the design, fabrication, test and calibration of a three-channel scanning radiometer for measurement of atmospheric emissions in the night-time equatorial sky. The instrument was fabricated under Contract No. F19628-67-C-0322 and the data was analyzed and reduced under Contract No. F19628-70-C-0215. The design, development of the instrument is given in the following report.

Clair L. Wyatt, "A Three-Channel Scanning Radiometer -- Model WS-1", *Scientific Report No. 2*, AFCRL-70-0384, Contract No. F19628-67-C-0322, Electro-Dynamics Laboratories, Utah State University, Logan, Utah, June 1, 1971.

Abstract

A three-channel scanning radiometer was launched into the equatorial night to obtain atmospheric emissions at 1.0,

1.27, and 1.6 micrometer wavelengths. The combined effect of ACS spin and instrument scan motion provided 22 vertical scans for each of six rocket rotations. Thus, data were obtained from the solar-illuminated twilight to the night sky.

The successful launch provided good data on the hydroxyl and oxygen emission bands. The signal levels were lower in absolute intensity than expected; data processing is recommended to achieve higher signal-to-noise ratio. Interesting variation in heights of the emission layers were observed.

The following two reports provide a detailed analysis of the data acquired with the three-channel scanning radiometer during a night-time launch at Natal, Brazil.

Ruey Y. Han, Lawrence R. Megill, and Clair L. Wyatt, "Reduction and Analysis of Natal Brazil Flight Data", *Final Report*, AFCRL-72-0018, Contract No. F19628-70-C-0215, Electro-Dynamics Laboratories, Utah State University, Logan, Utah, January 11, 1972.

Abstract

Observation of the Equatorial 1.27 Glow Shortly After Sunset

A rocket was launched at Natal Brazil (5.854° S and 34.832° W) on 9 March 1969, approximately 2 hours and 9 minutes after local ground sunset. This rocket carried, among other instruments, a 1.27-μ photometer. The photometric observation was auxiliary to a horizon scanning experiment and as a consequence viewed the 1.27-μ radiation, from above and over a large distance, which may be interpreted as a range of local times. The experiment was thus able to explore the time decay of the 1.27-μ emission at one time. The height of the emitting layer was 80 ± 5 km. The brightness (converted to overhead intensities as viewed from below) was about 200 kilorayleighs in the east and about 500 kilorayleighs in the west. Details of the intensity pattern will be discussed.

Ruey Y. Han, L.R. Megill, and Clair L. Wyatt, "Rocket Observation of the Equatorial $O_2(^1\Delta_g)$ Emission After Sunset", *Journal of Geophysical Research*, 78(27); pp. 6140-6149, 1973.

Abstract

A rocket was launched at Natal, Brazil (5.854^{o} S and 34.832^{o} W), on March 9, 1969, approximately 2 hr 9 min after local ground sunset. This rocket carried, among other instruments, a 1.27-μ radiometer. The photometric observation provided vertical scans through the earth limb throughout 360^{o} of the azimuthai angle and as a consequence viewed the 1.27- radiation from above and over a large distance. The region under observation covered a period of time ranging from 1 to 2½ hours after local sunset at 80 km and a range of latitudes from 4^{o}N to 16^{o}S. On this flight a prominent emitting layer with a thickness of approximately 10 km was observed at 80 ± 5 km. The data show a decay related to time after local sunset of this layer from 550 kR in the west (42^{o}W) to 250 kR in the east (22^{o}W). An intensity pattern that is about twice as strong at the equator as at 12^{o}S was also observed.

THE LABORATORY SPECTROMETER PREAMPLIFIER

Another objective related to this contract was the design of a laboratory spectrometer preamplifier to be utilized in a high-vacuum cryogenic laboratory system. This work is reported in the following design report.

Clair L. Wyatt and David E. Morse, "Design Evaluation Report For Laboratory Spectrometer Preamplifier, Model LSP-1", *Research and Design Evaluation Report,* submitted to Contract Monitor Dean F. Kimball under Contract No. F19628-72-C-0264, Electro-Dynamics Laboratories, Utah State University, Logan, Utah, 30 April 1974.

No Abstract

MULTIPLEXED SPECTROMETER STUDIES

One other paper resulted from this study and represents a probe into other possible applications of low-background detector technology.

This is in the application of multiplexed dispersive spectrometers to cryogenically-cooled LWIR detectors.

Clair L. Wyatt and Roy W. Esplin, "Multiplexed Dispersive Spectrometers Using Reduced Background IR Detectors", *Applied Optics*, 13( ), 1974.

Abstract

The application of multiplex spectrometry to cryogenically-cooled LWIR extrinsic-photo detectors is limited by system noise. This noise limitation results in a detector NEP that is directly proportional to bandwidth. Therefore, multiplex schemes that require increased bandwidth are not productive of real advantage. However, doubly encoded systems that are based upon 2n-1 or n+N-1 measurements have the potential to provide a real throughput gain proportional to the number of elements used on the throughput matrix.